CASPER conduction of a test program of realistic situations: misuse, postural change, inappropriate use

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Introduction

The performance of a Child Restraint System (CRS) is strictly influenced by the quality of its use. During the CASPER project (co-founded by EU Commission in VII FP) misuses of CRS have been observed in field and tested dynamically, in order to evaluate the effect of these misuses on the protection of children.

Based on recent field data collected in the frame of the project and through partnerships, a new test program has been defined. The testing program was based on the following realistic situation: inappropriate use, wrong installation and child posture.

The current study presents the operative approach followed by CASPER partner and the results of a detailed test program based on the evaluation of realistic and possible situation about typical misuse: wrong fixation of the CRS, wrong child restraining, inappropriate use, child postural. The new defined test program is complementary to the one of test results already available (CHILD project).

The operative approach

Using a common method and data collection form the CASPER partner have collected field data about how the children are restrained in the car. The analysis and relative evaluation have highlighted typical misuses that could influence the child safety in car.

The test matrix (coming from the previous CHILD works on the misuse and CRS) was updated with new configurations coming from real life observations and with new possible misuse due to the development of new products on the market.
With reference to the only frontal impact, during the CASPER project several dynamic tests were performed and 3 partners of the project directly contributed to this work: BASt, FIAT and GIE RE PR. Generally partners were free to choose the misuse configurations they intend to test but priorities were given to misuse configurations with ISOFIX systems that are normally developed in the aim of reducing misuse but that are not completely avoiding them: parents are not always aware or cautious of green indicators located on the different parts of the CRS.

All tests were based on a common methodology: the comparison between each “misuse” configuration with a reference test was performed according to ECE R44.
In all tests Q dummies (Q0, Q1.5, Q3, Q6) were used a Q dummies series (Q0, Q1.5, Q3, Q6) and CRS made available by several CRS manufacturers for the CASPER project activities. The tests were indifferently performed in a specific car environment (car body in white) or on a regulation bench depending on the possibilities of the test facilities in which they were run.

The testing program was based on the following misuse key topics:

- **Misuse**: in child system, in CRS attachment with seat belt, about ISOFIX Systems
- **Inappropriate use**
- **Postural**

Results

Totally 41 dynamic tests were performed:

- 19 tests are about misuse: 4 tests are about misuse in child system, 6 tests are about wrong seatbelt route, 9 tests are about wrong ISOFIX CRS fixation,
- 11 dynamic tests about inappropriate use of the CRS,
- 11 dynamic tests about dummy posture, sometimes mixed with a common misuse.

In the following for each misuse key topic are reported a table where are summarized the tests performed. The table contains the references to be used for analyzing in deep each performed test (biometrics data, tables, graphs) in the CASPER deliverable 3.1.2. This new document is going to be available on the CASPER website as soon as validated.

It has to be reminded that results are only applicable to the tested configurations (CRS, dummy, type and severity of impact), but global tendencies can be outlined:

- **Dummy behaviour**: dummies are not able to measure the full range of injury risks (e.g. effect of having the seatbelt twisted for children using a booster seat, excessive slack in harness,…).
- **Dummy instrumentation**: in a lot of cases, differentiating events using standard dummy readings is not an easy task. Films are helpful to see differences in global kinematics. Abdominal sensors are also good predictors to prevent injuries in this area. For the moment this sensors are not part of the standard equipment of Q series dummies but only at an advanced stage of prototypes.

1. Test about Misuse in child system

The misuse about child restraint was explored with several tests in CHILD project; during the CASPER project the field survey has shown that about the 35% of the child continues to be fixed in a wrong way. In the table 1.1 all performed tests are shown.

TABLE 1.1 - Misuse in child system– test performed

CRS Type	CRS Group	Misuse code	Description	Details	Partner
Rearward facing CRS	0+	1.1.5	Harness under the arms	ISOFIX	FIAT
Booster cushion with backrest	2/3	4.1.7	Seatbelt under the arm	Popular CRS on market	FIAT
Booster cushion with backless	2/3	4.1.4	Seatbelt over horns	- Booth straps over horns - Booth over internal horns	GIE PR
Booster cushion with backless	2/3	4.1.8	Use of add-on	Seatbelt – no backrest	GIE PR

In the misuse configuration shown in figure 1.2 the base and carrycot are correctly installed but the harness of the CRS is positioned under the arms of the Q1.5. Considering the type misuse the upper part of dummy was not restrained, and this allowed the possibility for the child dummy to slide out of the CRS, following the seat back inclination. The head is exposed to a high risk of impact against a rigid part of the car. In the rebound phase, the child is coming out of the restraint system and could be subject to severe injuries.

Figure 1.2: harness under the arms

The figure 1.3 shows a very common misuse configuration about group 2/3 (7% of the observed field data), using a very

popular CRS. This misuse was also detected in a real accident, reconstructed in Casper project (CCN 2032). The test was performed on the regulation bench using: pulse and the CRS similar to the ones used in the reconstruction, abdominal sensors in the Q3. Even if the position of the diagonal belt seems different between the reconstructed accident and the ECE bench (position of the belt anchorage points), the forces applied to the dummy in the misuse configuration seem to be realistic with regard to the child injuries in the real accident: head contusion, liver rupture, pancreas rupture, fracture of the 5th rib left, with pneumothorax.

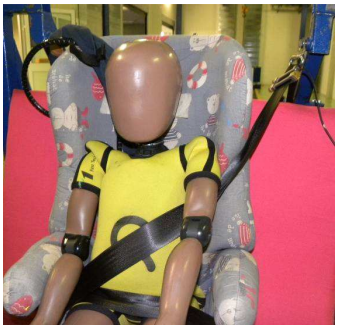

Figure 1.3: harness under the arms

In the figure 1.4 a commercial seatbelt adjuster was used applied to Q3 and to Q6 dummy. The seatbelt adjuster is a device created to help in the positioning of the upper part of the seatbelt. It should avoid interaction between the neck and the seatbelt and reduce the risk of neck wounds. Generally the results for both show a better behavior with this adjuster respect to the standard configuration.

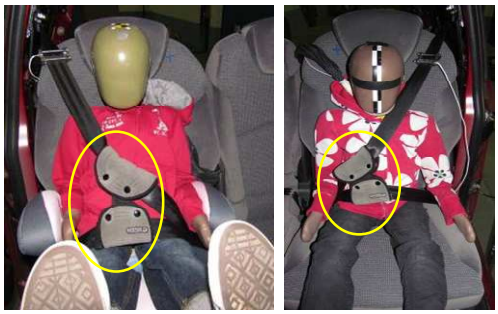

Figure 1.4: Seatbelt routes with "add-on" Q3 (on the left) and Q6 (on the right)

Contrary to this, the film analysis shows, that the diagonal part of the seatbelt is highly loading the lower part of the chest and the upper part of the abdomen from the very beginning of the test. The belt remains in that position until the end. These tests and some accidentology feedback show, that this device has some very dangerous side effects, because it amplifies the risk of submarining through a poor positioning of the belt on the abdomen even if used in combination with an approved CRS. Dummy readings are not able to translate this additional risk except when the abdominal sensor is used.

2. Test about Misuse in CRS attachment

The field survey has shown that about 22% of the CRS continue to be fixed in a wrong way. The main problem with the use of CRS is the correct belt path; also the rotation of the shell respect to the longitudinal direction could become a relevant problem. In the table 2.1 all performed tests are shown.

TABLE 2.1 Misuse in CRS attachments - test performed

CRS Type	CRS Group	Misuse code	Description	Details	Partner
Forward facing CRS Harness	1	2.2.7	Wrong seatbelt route	Upper seatbelt guide not used	BASt
		2.2.7	Wrong seatbelt route	"Normal" seatbelt use instead of specific	BASt
		2.2.8	Wrong seatbelt buckle		BASt
		2.2.8	Mechanical seatbelt pretensioner	No used	BASt
		2.2.8	Mechanical seatbelt pretensioner	Not locked	BASt
		2.2.9	Shell turned perpendicular to X axis	Seatbelt-different qualities of CRSs	BASt

Relevant are the effect linked to the configuration with the “Seat shell turned 90°” (fig. 2.2). The used CRS shell can be turned 90° to allow an easy attachment of the children. The shell has to be turned back afterwards.

Figure 2.2: Configuration with seat shell turned 90°: Reference condition; misuse; during the test

During this test the CRS was destroyed; the CRS shell separated from the base. The use of a CRS with a rotated shell has shown a complete reduction of the efficiency of the CRS leading to the ejection of the child dummy and the shell from the test bench.

3. Misuse in ISOFIX system - Wrong installation of the CRS

The field studies of the CASPER project have shown that less than 4% of the CRS were fixed with ISOFIX in the vehicle. The market penetration of this system is extremely considering that the vehicle fleet equipment of ISOFIX anchorages is around 50% (IBSR field data study - 2011). Several tests have been performed about this topic (ref. table 3.1)

TABLE 3.1: Wrong installation of CRS – test performed

CRS Type	CRS Group	Misuse code	Description	Detail	Partner
Rearward Facing CRS	0+	1.3.1	Support leg - Wrong adjustement (too short)	ISOFix	FIAT
		1.3.2	Only one ISOFIX connector engaged	ISOFIX 1 Internal 2 External	FIAT
		1.3.3	Wrong fixation of CRS on basis	ISOFIX	FIAT
Forward Facing CRS Harness	1	2.3.1	Only one ISOFIX connector engaged	ISOFIX 3 Internal 4 External	FIAT
		2.3.2	Support leg - Wrong adjustment (too short)	ISOFIX -	FIAT
		2.3.3	Slack in Top tether (different lengths, different routing)	ISOFIX	FIAT
		2.3.4	Non use of top tether	ISOFIX	FIAT
Booster cushion with backrest	2/3	4.3.1	ISOFIX attachment not used	ISOFIX – high quality CRS	GIE PR
		4.3.2	Only one ISOFIX connector engaged	ISOFIX 5 Internal 6 External	GIE PR

Globally the wrong installation of the CRS with ISOFIX can lead to misuse for which the effect varies from no visible effect to the destruction of the CRS, with serious consequence for the child. According this is relevant for the parents to follow the CRS manufacturer instruction in order to fix properly the CRS to the car.

When the support leg is too short (the misuse condition is evidenced by a red indicator on the support leg) as shown in figure 3.2 the absence of the anti-rotation device produced a rotation with failure of the base and unlocking of the carrycot. The base of the CRS (ISOFIX base) rotates until the support leg is in contact with the floor of the vehicle and then breaks it. Simultaneously the carrycot rotates and unlocks from CRS base falling down towards the front passenger area. This misuse produces a high risk of child injuries due to the risk of impact against a rigid part of the car.

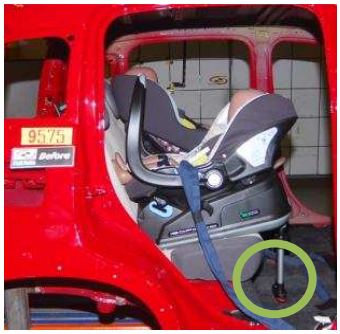

Figure 3.2: support leg too short

Using a combination CRS (system can be used rearward facing up to 10 kg and then forward facing as G1 CRS) critical misuse configurations were related to incorrect fixation of the ISOFIX anchorages. Independent of the connector that was correctly fixed (external or internal) the dynamic effect is similar: the CRS rotates around the anchorage that is properly engaged, causing a CRS movement with a high risk of impact against a rigid part of the car (i.e. vehicle B-pillar door/window) or another passenger. The misuse effects are influenced by the loads that occur at the level of the junction between the CRS base and the single anchorage properly fixed. At the end all CRS were still fixed to the car body by the engaged ISOFIX anchorage, but several damages were encountered.

In the figure 3.3 two misuse configurations using a Forward Facing G1 CRS with top tether as anti-rotation device are shown. In the first test some slack is introduced in the top tether (indicator is not green) and in the second one the top tether is simply not used at all.

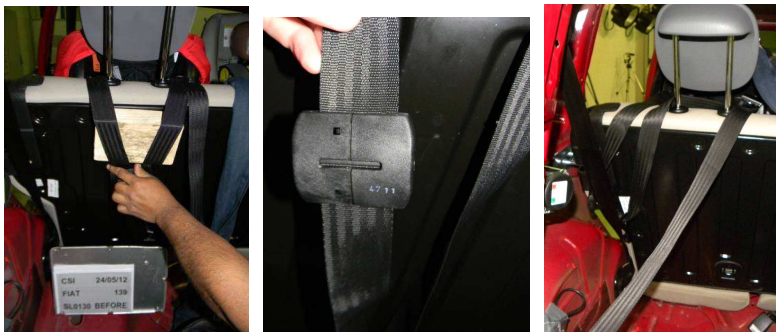

Figure 3.3: Illustrations of introducing slack in top tether, indicator not green and no top tether

The effects of such misuse are very depending on amount of slack in the top tether and could lead to serious consequence in the non use of top tether, for the absence of anti-rotation device. The risk of a contact between the child and the front passenger seat backrest becomes relevant.

4. Inappropriate use

Even if the choice of the restraint system for a child does not appear to be a large issue as most of parents, it is important to underline that ECE44 regulation classifying CRS using classes of weights with an overlap that is relatively large. When children grow, parents tend to change the restraint system too early. A CRS used for a child in the lower part of the weight group is globally less secure compared to another CRS used in its upper limit of weight, especially to switch from G0+ (up to 13kg) and G1 (9 to18kg). The rate of inappropriate restraint is becoming more important as the age of children grows, and the rate of children using only the seatbelt is becoming more and more important for children older than 7 years of age, for which the only seat belt is common used as restraint system.

Several tests are performed about this topic (ref. Table 4.1).

TABLE 4.1: CRS inappropriate use in frontal impact – Test performed

CRS Type	CRS Group	Misuse code	Description	Details	Partner
Forward facing CRS Harness	1	2.5.1	Wrong dummy size (Q0)	seatbelt	BAST
		2.5.1	Wrong dummy size (Q0)	ISOFIX	BAST
		2.5.2	Wrong dummy size (Q6) – overload	seatbelt	BAST
		2.5.2	Wrong dummy size (Q6) – overload	ISOFIX	BAST
Booster cushion with backrest	2/3	4.5.1	Wrong dummy size (Q1 ½)	Seatbelt – with backrest use as G1	FIAT
Booster cushion backless	2/3	4.5.1	Wrong dummy size (Q3)	Seatbelt – without backrest use as G3	GIE PR
Adult seatbelt only		7.5.1	Wrong dummy size (Q6)	Normal seatbelt route	GIE PR
		7.5.2	Use of add-on	Seatbelt – no backrest	GIE PR
		7.5.3	Dummy posture – foot on bench cushion	incorrect seatbelt position	GIE PR
		7.6.2	Dummy posture – far relax position	with correct seatbelt position	GIE PR
		7.6.3	Dummy posture - Reclined position of backrest	with correct seatbelt position	GIE PR

In figure 4.2 is shown the misuse configuration about the wrong child size, for a G1 CRS. Neither the Q6 nor the Q0 can be correctly restrained. For the Q6 the upmost shoulder strap position is too low, the harness is difficult to close and the dummy's head is fare above the CRS. For the Q0 the shoulder strap padding does not allow to tighten the harness.

Figure 4.2: Test set up with an ISOFIX CRS and Q3 (reference), Q6 (too heavy) and Q0 (too small)

Even though the measurements are not clear, it can be seen in film and photo analysis that the Q0 is not well restrained (Figure 4.3). It seems to be a dummy artefact that the Q0 sticks within the harness system. A child of this age/weight could escape from the harness during the impact.

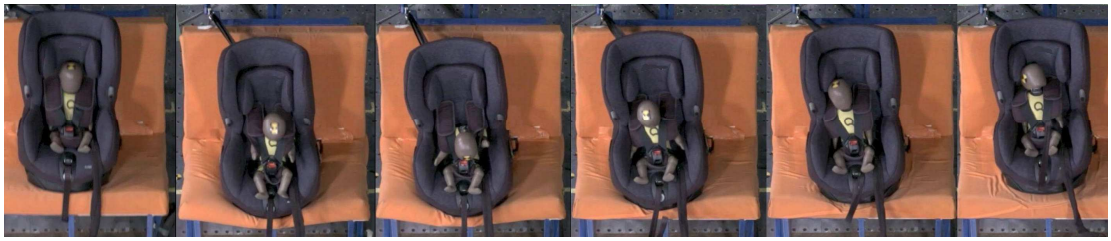

Figure 4.3: Film Sequences Q0 in a Group I CRS

The use of a Q6 dummy in the Group 1 CRS chosen, did not affect the CRS integrity. The dummy readings show lower values for the Q6 in comparison to the Q3 in the reference test. For the Q6, the film analysis shows that the head excursion increases a lot, so that the danger of head contact in vehicle crashes increases (Figure 4.4).

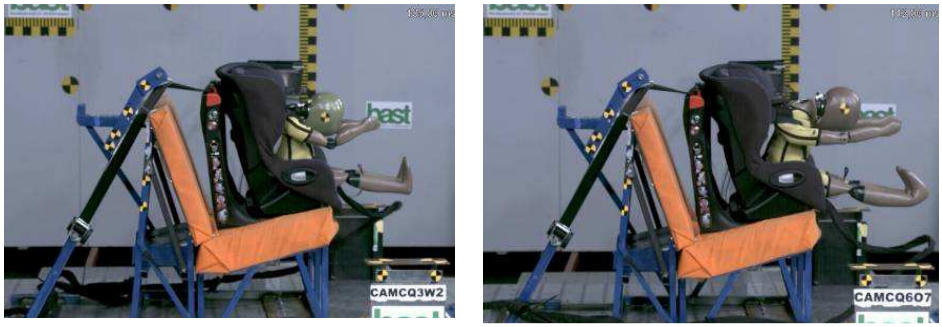

Figure 4.4: Comparison of the head excursion Q3 reference test – Q6 (belted CRS)

The test with the inappropriate use of the 3-point belt only with a Q6 was conducted in a body in white and compared with a Q6 test with a booster with backrest. The Q6 was equipped with abdominal pressure sensors. The abdomen sensor values identify a severe risk of injury not visible with the conventional dummy measurements. The tests performed with the Q6 dummy equipped with the abdominal sensors are in line with the injuries observed in accidentology.

The use of the inappropriate CRS for children too young can lead to the ejection of the upper part or of the complete body from the CRS (escape at the level of shoulders) that can also lead to serious injuries. When used with a larger dummy, respect to the weight group of CRS, show additional injury risks can be detected because of a higher head excursion (risk of head impact with vehicle interior).

Considering the tests conducted with a Q6, without CRS (only seatbelt) there is a dramatic increase of the abdominal pressure with a high risk of sub-marining compared to the same test performed with a CRS.

5. Postural

The posture configurations were not considered as misuse in the past but the aim was to test configurations close to the ones observed in real life and have a better opinion of the real level of protection of children in cars. Very often such situations lead to additional injury risk for the child. It clearly appears that testing single misuse is not always sufficient: children are not necessarily using the correct restraint system regarding their height and weight and the postures they have while the car is running are not often the ones of the standard position of the dummy in the regulation. Therefore inappropriate use and postural tests had to be run sometimes in combination one with the others, to have a better understanding of the behaviors of children in cars.

Several tests are performed about this topic (ref. Table 5.1).

TABLE 5.1: Postural and frontal impact – Test performed

CRS Type	CRS Group	Misuse code	Description	Details	Partner
Booster cushion with backrest	2/3	4.6.2	Dummy posture – far relaxed position	ISOFIX - Correct seatbelt position - Misuse situations	GIE PR
Booster cushion backless	2/3	4.1.4	Seatbelt over horns	-both straps over horns -both straps over internal horns	GIE PR
		4.1.8	Use of add-on	Seatbelt – no backrest	GIE PR
		4.6.1	Dummy posture – lying on window	-Correct seatbelt position -Misuse situations	GIE PR
		4.6.2	Dummy posture – far relax position	WITH CORRECT SEATBELT POSITION	GIE PR
		4.6.3	Dummy posture - Reclined position of backrest	WITH CORRECT SEATBELT POSITION	GIE PR
		4.6.3	Dummy posture – torso bending (forward posture)	WITH CORRECT SEATBELT POSITION	GIE PR
		4.6.4	Dummy posture – feet on bench cushion	-.Correct seatbelt position - Misuse situations	GIE PR
		4.6.5	Dummy posture – twisted as to speak with other occupants	- Correct seatbelt position - Misuse situations	GIE PR

In the figure 5.2 several posture position in combination with typical and common misuse are shown using a Q6 dummy:

- Bending to the window and Seatbelt under the arm (on the left)
- Body Twisted and Seatbelt under the arm (on the centre)
- Feet on front seat (on the right)

Figure 5.2: Posture position in combination with typical misuse – using a Q6 dummy

Considering all tests performed three main factors influencing the behavior of a Q6 dummy:

- The presence of a Child Restraint System (with or without ISOFIX)
- The positioning in the seat (“Far relax”, Feet on front seat, sleeping)
- The compliance with the recommendation of the route for the seatbelt on the dummy and the seat

The dummy behavior in this condition is often very similar to the reference test, except for the abdominal sensors that detect the values upper the limits, these on the child are linked to the generation of abdominal injuries. The worst observed condition are: “Belt under the arm”, “Belt over the horn of the CRS”, “Far relax” position. Similarly all tests conducted on a Q6 dummy without CRS led to a dramatic increase of the abdominal pressure with a high risk of sub-marining (efficiency of CRS).

The same tests have been performed using a Q3 dummy; in this case the Q3 dummy has an inadequate instrumentation to see the influence of these types of “misuses”. For instance on a Q3 dummy it was not possible to see the influence of the “relax position” even if critical situation are visible on the videos; these non standard tests aren’t acceptable in comparison

with a real life situation, for the possible consequences on a child of 3 years, with a softer lumbar spine.

The Q3 dummy, in association with a CRS Group 2/3 without backrest several test are performed with aim to analyze the effect of different seatbelt route. In the figure 5.3 two different ways to install a child seat have been compared with a clearly defined misuse (wrong routing belt):

- Q3 in standard position without misuse (on the left)
- Q3 installed with an alternative child seat installation (on the centre)
- Q3 installed in a CRS with a wrong routing of the belt (on the right)

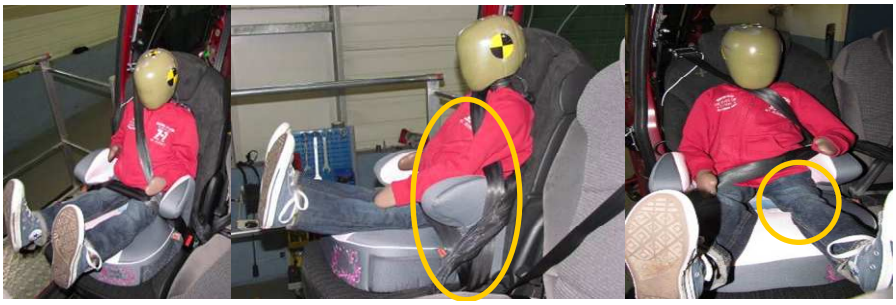

Figure 5.5: Different seat belt route.

For both dummies sometimes the test series have highlighted a right in some configurations it was found difficult to see an influence of the misuse, positioning or inappropriate use in the dummy measurements, but what is visible on high speed films clearly indicate that the situation is not safe. This may be due to the dummy instrumentation (or lack of instrumentation) or to the dummy behavior which is designed for a standard seating position and that might not be able to show a special influence, according to statures.

The analysis focuses on the compliance with the recommendations to install correctly a child seat in a vehicle. The most significant point of this campaign for this dummy is the route of the seatbelt which generate very high risk of abdominal injuries in case of bad positioning, visible in additional neck loads.

The main results linked to a possible effect of the child posture on the dummies behavior could be summarized in the following:

- **Postural effect**: when the child dummies are positioned in more relaxed (and more realistic) positions, the risk of sustaining serious injuries is higher for the head and for the abdomen: some head impacts and some seatbelt penetrations into the abdominal areas have been observed on films and dummy readings. In some postures, only the film is able to indicate that the dummy behave differently than in the reference tests.
- **Wrong seatbelt route on boosters:** is a critical misuse that leads to not restraining the upper part of the child dummy or to strong forces applied onto the lower rib cage and abdominal areas. When combined with postural situations, these misuses become even more critical for the safety of the considered children.

Conclusion

During this test series it clearly appears that a large number of misuse situations have a clear influence on the safety of the child but in some configurations it was found difficult to see an influence of the misuse, positioning or inappropriate use in the dummy measurements. Fortunately, what is visible on high speed films clearly indicate that the situation is not safe. This may be due to the dummy instrumentation (or lack of instrumentation) or to the dummy behavior which is designed for a standard seating position and that might not be

able to show a special influence, according to statures. The test showed that a very important part to look at is the abdomen. The abdominal sensors in the Q6 seem to be a good tool to evaluate the risk of injury on this body part and the could give also important information on this body region for the Q3.

At same time all performed tests highlight that it is very important to communicate to children that the correct use of the seatbelt is crucial for their safety and that it has to be combined with the use of a booster seat until their size is close to the one of adults. Messages for adults should start with the fact that children always need to be restrained while travelling in cars. The choice of an appropriate CRS, its correct installation in the vehicle and the seatbelt route for children on boosters are essential requirements to guarantee the highest protection level for children. Some systems are easier to use than others, equipped with indicators telling if installation and adjustments of different parts are correct (such as ISOFIX). Of course, they still require a minimum of attention to be correctly installed and it's important to check their compatibility with the vehicles in use before purchasing them.

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